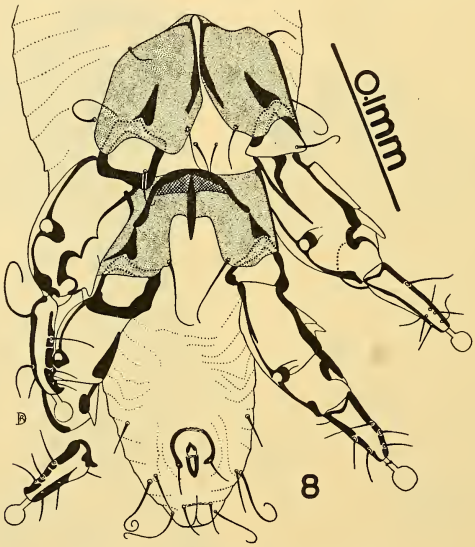
Mid-dorsum with about ten simple cuticular annulations, the remainder of the dorsum being covered by annulations which form a pattern medially. Dorsal cuticle with seven pairs of simple setae, and without long terminal setae. The annulations pass ventrally, and behind coxae IV they run back medially to form a furrow. Three pairs of setae are present ventrally in addition to four flanking the terminal, longitudinal anus.

Ovum single, elongate, with almost parallel sides and rounded ends, average size 214μ long, 64μ wide; range 204 by 60 to 221 by 68μ.

Legs I and II very strongly sclerotized, flattened, with retrorse knobs and distinct caruncles. The clasping organ is transversely striate, with a pair of setae between coxae II. Coxae III not joined, with antero-median angles rounded and sclerotized, and postero-median corners transparent and produced into large pointed lobes. A pair of setae are present beneath these lobes, and also a pair of accessory transverse-striate



Text-fig. 8.
Austrochirus enoplus, n.sp. Male, ventral.

clasping organs. Two setae are present directly above the dorsal margin of coxae III, and a further seta above these just behind the ventral encroachment of the dorsal shield. Legs III simple, tarsi III with about eight setae. Coxae IV not joined, broad and sclerotized, with a seta at inner posterior angle. Leg IV similar to leg III, tarsus IV with about seven setae. The other movable segments of legs III and IV have no setae. Articulatory processes for legs III and IV small.

Average length 448μ, range 404 to 498μ.

Male.

Similar to female dorsally and anteriorly. Ventral annulations irregular, with three pairs of setae in addition to four flanking anus. Genitalia surrounded by sclerotized arc, which bears a seta at each posterior end. Intromittent organ between these two setae, short, sclerotized, and projecting backwards.

Legs III and IV greatly enlarged and heavily sclerotized, with long transparent flaps along ventral margin, and with peculiar looped sclerotizations dorsally. Basal

movable segment of leg III with a single seta, but leg IV without such a seta. Tarsi with small internal apical hook in lateral view, and normal caruncles. Tarsus III with strong curved seta basally, and about seven smaller setae. Tarsus IV with about six setae. Articulatory processes for legs III and IV larger than in female.

Average length 449μ, range 404 to 482μ.

Distribution.

Known only from the type host and locality in North Queensland.

Discussion.

There are two other described species of *Austrochirus*, both of them also Australian—*A. queenslandicus* Womersley, 1943 (genotype) and *A. sminthopsis* Womersley, 1954. Although the three species are readily separated on several characters, they fit easily into the genus, having a number of points in common—a single antero-dorsal shield, the median lobe of which is surrounded by four setae, a strong curved apical seta on tarsi I and II, a similar basal seta on tarsus III of the male, legs III and IV noticeably enlarged in the male of two species. *A. enoplus* and *A. sminthopsis* both have a three-lobed dorsal shield, but I believe the former to be more closely related to *A. queenslandicus*. The relationships are shown in the following key.

Womersley's two species are known only from marsupials of the families Phalangeridae, Peramelidae and Dasyuridae, while the species described above was taken on a rat. The three undescribed species in the Trouessart collection are all from dasyurids.

Key to species of Austrochirus *Womersley.*

1*a*. Cuticle of both sexes covered with small pointed papillae; male with legs III and IV not noticeably enlarged ..... *A. sminthopsis* Wom.

1*b*. Papillae, if present, flattened and scale-like, and confined to venter of female; male with legs III and IV enlarged and heavily sclerotized ..... 2.

2*a*. Only median lobe of dorsal shield present; postero-dorsal annulations not forming a median pattern; end of body with long setae. Female without accessory claspers between coxae III, but with scale-like markings on venter. Male without looped sclerotizations on dorsal edge of legs III and IV ..... *A. queenslandicus* Wom.

2*b*. Median lobe of dorsal shield enclosed by two lateral lobes; postero-dorsal annulations forming a pattern medially; end of body without long setae. Female with accessory claspers between coxae III but without scale-like markings ventrally. Male with looped sclerotizations on dorsal edge of legs III and IV ..... *A. enoplus*, n.sp.

Acknowledgements.

I am indebted to Mr. H. Womersley for the opportunity to redescribe and figure *Campylochirus chelopus*, and for the loan or gift of type and paratype material of his two described species of *Austrochirus*. Dr. Marc André kindly allowed me to examine the three undescribed Australian species attributed to *Campylochirus* from the Trouessart collection, and provided a list of relevant species still present in that collection. Dr. W. A. McDougall kindly identified the host of *Austrochirus enoplus*.

Reference.

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PHYSIOLOGIC SPECIALIZATION IN CROWN RUST OF OATS.

By E. P. Baker and Y. M. Upadhyaya, The University of Sydney.

[Read 26th October, 1955.]

Synopsis.

Studies on physiologic race specialization within the organism causing crown rust of oats, *Puccinia coronata avenae* F. & L., are presented from field collections made in eastern Australia during the period 1952-54. These studies were conducted on the new differential set of ten varieties devised by North American workers with the object of assisting plant breeders in a more direct manner. Whilst assessing its merits for local conditions, studies were also continued on the former set.

These investigations revealed a considerable range in pathogenicity. Eight races were recorded on the new and ten on the former set. Of particular importance was the occurrence of a race attacking the variety "Victoria" within either series. This was first detected in the field on the variety "Vicland", but now occurs on other varieties. Its geographical range has continued to increase and at the present time occupies a wide area. Races attacking another important source of resistance, "Bond", are still found occasionally in the field, but do not appear to increase to any extent. A race attacking the varieties "Trispernia", "Landhafer", "Santa Fe" and "Mutica Ukraine", which were specifically introduced for breeding against rust, was found at Castle Hill Research Station, in very small amounts on adult plants of these varieties. This race is peculiar to the Australian continent and has been assigned race No. 286 by the central authorities at Ames, Iowa, U.S.A.

In view of the changes in the varieties used in breeding for resistance the new set has greater merit in assisting plant breeders. It is suggested that it should be used for Australian determinations with the inclusion of the extra-differential variety "Klein", and certain others in the former set, for determinations of local biotypes. Difficulties in biotype nomenclature within races are discussed.

In view of the absence of the alternate host plants (*Rhamnus* spp.) in Australia and the absence of experimental proof that heterocaryosis produces variability for pathogenicity, changes in virulence can only be accounted for by step-wise mutation. In certain instances mutations for pathogenicity may apparently encompass more than one varietal source of resistance.

Aspects of breeding for resistance include suggestions for incorporating genes by interspecific hybridization, experimental production of host plant mutations for resistance within economic varieties and the use of combined resistances to give more permanence in the usefulness of newly released economic varieties.

As a factor affecting oat production in New South Wales, crown rust, *Puccinia coronata avenae* F. and L., is of perhaps greater importance than stem rust, *P. graminis avenae* E. and H. Infections are especially severe in coastal areas. Frequently young crops are ruined before grazing is possible. The need for crown rust resistant varieties is also paramount in coastal areas of Queensland. Advanced oat crops heavily infected with crown rust lodge badly and ripen prematurely.

In general, breeding for crown rust resistance had received little attention in economic breeding programmes throughout Australia until recent times. In recent years a strain of "Victoria" × "Richland" named "Vicland" was introduced from the United States into Queensland, crown rust resistance being derived from "Victoria". Other varieties grown commercially on account of their crown rust resistance have been "Fultex" (a "Fulghum" × "Victoria" derivative introduced also from the United States) and "Klein 69B", which has had some resistance in New South Wales. In Queensland the resistance of "Klein" has not been regarded as high, but it has been observed that the first pustules on this variety appear a week or so later than those on varieties such as "Algerian" (Dr. L. G. Miles, personal communication). The variety "Bovah" was released by the Queensland Department of Agriculture and Stock in 1953; it was selected from a three-way cross between ("Bond" × "Victoria") × "Hajira" (Miles and Rosser, 1954). It therefore has two crown rust resistant varieties, Bond and Victoria, in its pedigree.

Review of Literature on Physiologic Specialization Studies.

As with all cereal rusts studied in any detail, physiologic specialization has been shown to occur in *P. coronata avenae* and to be of considerable importance in oat breeding programmes. Hoerner (1919) was the first to demonstrate physiologic specialization in the fungus and described four races. He distinguished these by the types of infection produced on two differential oat varieties, "Ruakura" and "Green Russian". Different workers in both North America and Europe then described various races showing that the phenomenon of physiologic specialization was widespread. Murphy (1935) isolated 33 races of crown rust of oats from collections obtained in the United States, Canada and Mexico. He demonstrated that the 33 races embraced all those isolated by previous North American workers, and proposed a standardized numerical designation for them. In Europe, Straib (1937), using 15 varieties, differentiated 142 races in Europe. However, Murphy and his associates at Iowa State College, Ames, Iowa, U.S.A., have been recognized as the centre for race identification and assignment of race numbers to appropriate cultures. The key to some 113 races was supplied by them in 1953. These races are primarily of North American origin, but include races identified in other parts of the world.

In Australia physiologic race surveys have been carried out by Waterhouse. For this purpose the standard set of differential hosts selected in 1931 by Murphy and Peturson (Peturson, 1935) has been used. Five races were described by Waterhouse (1938) and the Australian situation in general has been most recently summarized by Waterhouse (1952), where the distribution of races in time and space is indicated. These latter results covered a survey from 1935 to 1951. Thirteen races were described, race 6 constituting 50 per cent. of the determinations. Race 40 was first described by him, and races 102, 103 and 104 were new records, not being recorded elsewhere.

Inherent with these determinations are problems common to all rust physiologic race studies. It has frequently been observed that environmental modifications may markedly affect the reaction of a particular race on a pure line of a variety of the host plant. Temperature particularly has an effect in the case of crown rust; a low or resistant seedling reaction at lower winter temperatures may become a susceptible one at higher temperatures. On this account it is generally considered that the proper separation of races can only be carried out satisfactorily under relatively low temperature conditions. Since environmental factors influence infection type, it is possible that races described as distinct in different regions may actually be the same. Conversely, environmental differences may result in cultures described as the same constituting different races at lower temperatures. Doubtless all determinations should be made by a central authority under controlled conditions, but such a procedure is often impracticable. At the same time it is recognized that certain resistant reactions are little influenced by temperature. For example, the resistant reaction of the variety "Bond" seems little affected by increase in temperature. Peturson (1930) published critical data showing the effect of temperature on host reactions.

Introduction of New Differential Set.

The initial differential set of varieties selected in North America by Murphy and Peturson and used almost universally, including those for Australian determinations, comprised thirteen varieties belonging to different species of *Avena* as follows:

Avena sativa L.: Ruakura; Green Russian; Hawkeye; Anthony; Sunrise.
A. sativa orientalis Alefeld: Green Mountain; White Tartar.
A. byzantina C. Koch.: Red Rustproof or Appler; Sterisel; Belar; Bond; Victoria.
A. strigosa Schib.: Glabrota.

These varieties constituted a wide range in genotypes for studying reactions of different collections and hence determining the range in variability of the pathogen. However, at a recent conference of North American plant pathologists it was decided, commencing with the 1951 collections, to use a new revised set of differential oat varieties for crown rust determinations. There were indications that the varieties

previously used were inadequate for race identification, and it was not considered that the old differential set gave the help needed by plant breeders in a breeding programme for incorporating crown rust resistance into agronomic varieties. The need for a new differential set arose from a wide search for new genes for resistance to crown rust when resistances previously used proved susceptible to certain races. This has particularly applied to resistances derived from the varieties "Victoria" and "Bond". A race of crown rust capable of attacking "Victoria" was first reported by Murphy and Levine (1936) from a collection made in Texas. This race and others capable of attacking "Victoria" apparently were of no serious consequence in the field. However, in North America varieties possessing the "Victoria" type of crown rust resistance proved susceptible to a new soil-borne blight disease, Victoria blight, caused by *Helminthosporium victoriae* M. and M. The universal susceptibility of all varieties possessing the "Victoria" type of crown rust resistance to Helminthosporium blight indicated a close association between the "Victoria" type of crown rust resistance and blight susceptibility. On this account the growing of varieties in North America with the "Victoria" type crown rust resistance was discouraged; these varieties included "Garry" and "Beacon" in Canada, and "Vicland" and "Tama" in the United States. It has been recently shown by Welsh, Peturson and Machacek (1954) that resistance to race 4 and certain other races is controlled by a single dominant gene which is linked with susceptibility to Victoria blight in strains of "Victoria" parentage. In the case of race 45, and certain other races similar to it in inheritance, resistance is conditioned by three dominant genes. The authors found one of these factors to be one for a weaker type of resistance, similar to that shown to race 4, which appeared to be linked with susceptibility to Victoria blight. A factor for high resistance to the race 45 group apparently is not associated with Victoria blight susceptibility.

Attention was then turned to "Bond" as a source of crown rust resistance by oat breeders as it possessed resistance to Victoria blight. In the United States, however, "Bond" and its derivatives proved susceptible to three new races—34, 45 and 57. These races were at first sparsely distributed, being found chiefly in the southern United States winter-oat area. Race 45, however, increased in prevalence and caused considerable losses in the north-central portion of the winter-oat area. Newly released varieties, such as "Clinton" and "Benton" with "Bond" resistance to crown rust and outstanding agronomic qualities were severely attacked. This led to a search for new sources of crown rust resistance. The varieties "Trispernia", "Landhafer", "Santa Fe" and "Mutica Ukraine" were considered to be of great value in this connection. "Trispernia" was introduced from the Botanical Gardens, Cluj, Roumania, into North America. "Landhafer" was introduced into the United States from Germany under the name "Landhafer aus Uruguay", and probably originated in South America. "Santa Fe" originated in South America as a pure line selection made from an unnamed commercial oat variety. "Mutica Ukraine" was introduced into the United States from Russia in 1930 and the name subsequently shortened to "Ukraine". Information on the origin of these varieties is obtained from Welsh *et al.* (1953). These four varieties were included in a new differential set of ten varieties to test their reactions to collections of crown rust and hence anticipate their usefulness to oat breeders. In the new differential set, "Anthony", "Victoria", "Appler" and "Bond" were retained from the old set and the varieties "Bondvic" and "Saia" were added, so that the new set comprises the following varieties:

A. sativa: Anthony; Santa Fe; Trispernia; Ukraine; Bondvic.
A. byzantina: Bond; Landhafer; Appler; Victoria.
A. strigosa: Saia.

Under the new system of race designations, races are given new numbers commencing at 201.

The problems confronting Australian oat breeders have been remarkably similar to those in North America. Waterhouse (1952) described two races, 45 and 57, capable of attacking "Bond". In the spring of 1951 the variety "Vicland" at Lawes, Queensland,

was observed attacked by crown rust. This collection was susceptible on "Victland" and "Victoria" seedlings in tests conducted by Professor Waterhouse. This race, as indicated later, has considerably increased in distribution since 1951. Victoria blight has also recently been reported from Queensland (Miles and Rosser, 1954).

These circumstances have necessitated a similar need to that experienced in North America for new sources of crown rust resistance. In this connection Australian breeders have largely been guided by North American experience, since the problems have been parallel. The varieties "Landhafer", "Trispernia", "Santa Fe" and "Ukraine" are being used in this country for crown rust resistance breeding programmes. It seems desirable to give the present information on race designations and host plant reactions for assistance to oat breeders throughout the Commonwealth and also for comparison with overseas race designations on the new differential set. A survey of 1952 to 1954 collections as to location and race will be presented in a separate paper when the testing for the current season is completed.

Procedure in Race Determinations.

Seedlings of both the old and new differential sets were inoculated when the first leaf was two to three inches in length, as described by Murphy (1935). After moistening, rubbing and remoistening the leaves, rust inoculations were made with a flat needle or by the bulk inoculation method. In the latter method uredospores from well-infected pots were dusted onto pots of seedlings, which were then incubated in a moist chamber for approximately 36 hours. As inoculations were done at relatively low temperatures, this incubation time rather than a shorter one was adopted. Different cultures were maintained in separate glasshouses as far as practicable to prevent contamination. After incubation the pots were stood on well-lighted benches. During higher summer glasshouse temperatures, use was made of a temperature-controlled, artificially illuminated chamber. Use was also made of this chamber for critical comparative reactions under constant environmental conditions throughout the year. The chamber was illuminated by batteries of fluorescent lights suspended about three feet over the benches. The tubes were about two inches apart and the intensity in the region of the plants was determined to be 400 foot-candles. Four-feet daylight type tubes were used, but the light from them was found to be deficient in the red end of the spectrum and caused a tip-burning of the oat seedlings. The quality of light in this region was supplemented by incandescent bulbs—four of 100 watts each being supplied per battery. Readings indicated that the light intensity was not appreciably increased. The temperature was controlled thermostatically by air blown over a refrigeration unit. The temperature was maintained at 65° F. with a variation of ± 2° F.

Infection types on host plants were designated according to the scheme outlined by Murphy (1935), which is based on that described by Stakman, Levine and Bailey (1923) for *P. graminis avenae*. For mesothetic reactions the symbol X, which is now more conventionally used instead of M, was adopted. Plus and minus signs were used to indicate variation within a given type, and the superscript symbols ^{c} and ^{n} to indicate chlorosis and necrosis respectively. Infection types were recorded approximately twelve days after inoculation and checked three days later.

If sufficient inoculum was available on the original collection, sets were immediately inoculated. If only a small amount was available, the collection was first built up on susceptible varieties such as "Burke" and "Richland".

Experimental Results.

Reaction of Races and Collections on New Differential Set.

Seed of varieties in the new differential set was made available by Dr. H. C. Murphy in 1952. Cultures maintained at Sydney University and new accessions were then tested on both the new and old differential sets. The reactions on the new set are tabulated in Table 1, together with the old race designations.